TITLE

APPARATUS AND METHOD FOR INTERFERING WITH PATHOLOGICAL CELLS SURVIVAL PROCESSES

DESCRIPTION

Field of the invention

The present invention generally relates to an apparatus for interfering with pathological cells survival processes.

In addition, the invention relates to a microbiological method carried out by such apparatus for interfering with pathological cells survival, in particular cells affected by cancer and other diseases caused by alterations in the mechanism of cell survival.

In particular, the interference is induced by means of static (S) and extremely low frequency electromagnetic (ELF) fields produced by the apparatus.

Magnetic Static fields and Extremely Low Frequency electromagnetic fields are hereinafter referred to also as S and ELF, respectively. Moreover, any possible combination of different sequences of S and/or ELF fields, such as S fields followed by ELF fields, ELF fields followed by S fields, S and ELF field together, as well as the presence of S or ELF fields alone, will hereinafter be referred to also as SELF fields.

Background of the invention

It is known that pericellular fields and currents induced by an Extremely Low Frequency (ELF) electromagnetic field, whose frequency range is from 1 Hz to 300 Hz and perhaps up to 1000 Hz, induce within the cell certain membrane electrochemical events which are important for primary biologic signal transduction and amplification processes.

These biochemically mediated events then produce cytoplasmic second messengers and internal effectors such as free Ca^{++} and protein phosphorylases (kinases) which in

turn trigger certain changes in the biosynthesis of macromolecules as well as bring about alterations in cellular growth differentiation and functional properties [[1]M. Blank, 1993].

Further, the possibility that S and ELF fields affect the DNA synthesis, DNA integrity, transcription and translation has been documented [[2]Liboff 1984, [3]Tofani 1995, [4]Goodman 1991, [5]Phillips 1992].

A possible physical mechanism to account for some of the experimental findings is the direct effect on ions (i.e. Ca^{++}) or on ligand binding at the cell membrane [[6]Liboff 1985, [7]Chiabrera 1985, [8]Lednev 1991, [9]Blanchard 1994].

The possibility of influencing variations of Ca^{++} metabolism may lead to cell apoptosis (programmed cell death) [[10]Preston, [11]Trump 1997].

Another physical interaction mechanism is related to the possibility of influencing the kinetics of appropriate cell signalling pathways of the cell (including calcium metabolism) through a field direct effect on electron-spin motion of atoms and molecules with unpaired electrons. This influencing may affect the recombination ratio of a spin correlated free radical pair and consequently on redox signalling [[12]Grundler 1992; [13]Polk 1992; [14]Walleczek and Budingher 1992; [15]Adey 1993].

In particular, the spin singlet-triplet energetic level transition in a free radical is critical for increasing the recombination ratio of spin correlated free radical pairs.

The possibility for low level, non thermal (with intensity up to 30 mT) S and ELF magnetic fields to influence in vitro the kinetics and efficacy of radical pair reactions is known from magnetochemistry [[16]Steiner 1989].

Naturally occurring free radicals have an oxygen-

or nitrogen-based unpaired electron such as superoxide anion, hydroxyl radical and nitric oxide. These Reactive Oxygen Species (ROS) and Reactive Nitrogen Species (RNS) can target proteins providing an obvious mechanistic explanation for free radicals-mediated signalling events. These events may influence growth factors, ion transport (i.e. Ca^{++} channels), transcription, apoptosis [[17]Lander 1997].

Apoptosis is a morphologically distinct form of programmed cell death that is connected in cell survival processes playing an important role during development, homeostasis, and in many diseases including cancer, acquired immunodeficiency syndrome, and neurodegenerative disorders, as well as in other diseases that similarly to those are characterised by altered cell survival processes. Apoptosis occurs through the activation of a cell-intrinsic suicide program. The basic genetic mechanism of apoptosis appears to be present in essentially all mammalian cells at all times, but the activation of this suicide program is regulated by many different signals that originate from both the intracellular and the extracellular environment.

Among all the genes involved in apoptosis regulation, the p53 gene is receiving much attention. This gene, which encodes a transcription factor and is common in many human cancers, mediates the cellular responses to some environmental damage. The p53 protein either can temporarily stop cell division, so that the cell can repair altered DNA, or can pilot the cell to an apoptotic death.

Published data support that p53 appears in apoptosis through a three step process: 1) transcriptional induction of redox-related genes: 2) the formation of reactive oxygen species and 3) the oxidative degradation of mitochondria components, culminating in cell death

[18Polyak 1997] .

In addition anti-oxidative agents are combined with drugs in the treatment of hypoxia tumour cells [19] [Walch, 1988] and in the influence of vascular growth factor [20][Amirkhosravi, 1998].

Moreover, published data are supporting the idea that pathological cells answer differently than normal cells to ELF fields stimuli. According to [21]Cadossi [1992], lymphocytes from normal patients respond differently than lymphocytes from Down's syndrome, AIDS and chronic lymphocytic leukaemia patients when exposed to ELF fields (previously with mitogen).

It is also recognised that Ca^{++} influx across the membrane is influenced by ELF fields in leukaemic lymphocytes but not in normal lymphocytes [22Walleczek, 1996].

Altered cell survival processes come with electric disorders and different electrical behavior. In fact, rapidly proliferating and transformed cells have electrically depolarized cell membranes if compared with normal cells [23Binggeli, 1986;24 Marino 1994]. It has also been shown that epithelial cells lose their transepithelial potential during carcinogenesis [25Davies 1987; [26] Goller 1986; [27] Capko, 1996]. This different electrical behavior of tumor cells compared with normal cells is the basis for a newly proposed cancer diagnostic modality [28Cuzick 1998]. In addition, the concentration of free radicals in transformed cells and tissues is higher than in non-transformed ones [29Szatrowski 1991; [30] Shulyakovskaya 1993; [31] Iwagaki 1995].

With reference to chemotherapy all efforts are devoted to the target of inducing cell apoptosis in vivo instead of killing them, through Signal Transduction Directed Therapy (STDT) of cancer [32Levin, 1998].

Signal Transduction is a functional term that

connotes the translation of genetic information into signalling cascades that allow the cell to for example interpret and respond to external stimuli and/or duplicate itself. Recent evidence suggests that alterations in the cell survival processes contribute to the pathogenesis of a number of human diseases, including cancer, viral infections, autoimmune diseases, neurodegenerative disorders, and AIDS. Treatments designed to specifically alter the apoptotic threshold connected with the survival processes mechanisms may have the potentiality to change the natural progression of some of these diseases [[33]Thompson, 1995].

High intensity electrical, electromagnetic and magnetic fields have been used to destroy pathological cells.

In [34]US4665898 an apparatus is described in which animals having malignant cells are treated by means of a high intensity pulsed magnetic field, in order to neutralise/destroy malignant cells in a selective way. This apparatus produces magnetic thermal fields having intensity comprised between 1 Tesla up to 10 Tesla and reversing polarity in the range 5÷1000 Kilohertz. In the preferred embodiment the magnetic field intensity is set between 1 and 50 Tesla and in particular, in the examples, it is set at 5 Tesla and 8 Kilohertz up to 18 Tesla and 250 Kilohertz.

Different ELF, thermal, continuous or pulsed fields, have been used for anti-cancer therapy in vitro [[35]Narita, 1997; [36]Raylman, 1996].

In these cases the fields are of very high intensity, much higher than what people are allowed to be exposed by the safety standards, and may produce heating thus damaging normal tissues and cells.

ELF low intensity electromagnetic fields have been used as well to inhibit mitosis of malignant cells, such

as in DE 4122380A1 and US 5156587. However, these documents describe the use of sinusoidal fields only at a fixed net frequency and at a fixed intensity, with the possibility to sweep only a limited range of energy levels inside the cellular tissue.

Summary of the invention

It is an object of the present invention to provide a method for interfering with cell survival processes (i.e. inducing apoptosis) of living pathological cells (i.e. cancer cells) by using magnetic fields without adversely affecting normal cells.

It is another object of the invention to provide an apparatus for interfering with pathological cells survival processes.

The former and other objects are reached by the method for interfering with pathological cells survival according to the invention whose characteristic is to apply to living pathological cells (i.e. cancer cells and cells affected by other diseases caused by alterations in the mechanism of cell survival) non thermal SELF magnetic fields to induce apoptosis in a selective way.

For the purposes of the invention SELF fields are to be considered as different sequences of S and/or ELF fields, i.e. S fields followed by ELF fields, ELF fields followed by S fields, S and ELF field together, as well as the presence of S or ELF fields alone.

The concept underlying the method according to the invention is that SELF fields interfere with cell signalling sustaining cell pathological behaviour inside pathological cells, i.e. on redox signalling through free radicals, thus restoring the cell survival processes, i.e. inducing directly or indirectly apoptosis through a modification of p53 gene expression.

This method is supposed to recombine oxygen-based free radicals and may also be used as an anti-oxidative

agent. It's combination with drugs in the treatment of hypoxia tumour cells and in the influence of vascular growth factor may also be considered.

The reason why SELF fields selectively induce apoptosis in pathological cells (i.e. cancer cells) may be related to the altered electrical behaviour of pathological cells compared with that of normal cells.

For these reasons SELF fields can induce directly or indirectly a signal programmed cell death (apoptosis), in vitro and in vivo, without causing any adverse effect.

In the hypothesis that free radicals recombination is at the basis of the expected biological effects on pathological cells (i.e., anti-tumour activity) the transition between singlet-triplet of unpaired electron in oxygen based free radicals has to be considered. In fact this transition, which depends on the applied magnetic field, is critical for increasing the recombination ratio of a spin correlated free radical pair. However, the reaction centres related to the expected anti tumor effect are unknown and therefore the lifetime of the spin states and the energy splitting between singlet and triplet states cannot be precisely determined from the spin hamiltonian [[37]Haberkorn 1979, [38] Lersch 1983].

To encompass this problem, according to the invention, sequences of S magnetic fields with different intensity modulated in amplitude can be used, with the superimposition of ELF magnetic fields. The use of modulated fields is in agreement with the need for reaching optimal condition(s) for the singlet-triplet spin state conversion required for the free radical recombination processes [[13]Polk 1992].

For these reasons, S, ELF or SELF fields have higher probability to induce the expected biological effects if they are modulated following a predetermined function of intensity and or frequency versus time, since this way the

probability to induce the above transition is higher.

The different sequences of S and/or ELF fields sequences are advantageously set for time intervals T_1, T_2, ▒, T_n, wherein the intensity I_s, I_{ELF} and their ratio I_s/I_{ELF} are set at steady values I_{s1}, I_{s2}, ▒, I_{sn}; I_{ELF1}, I_{ELF2}, ▒, I_{ELFn}, I_{s1}/I_{ELF1}, I_{s2}/I_{ELF2}, ▒, I_{sn}/I_{ELFn}, respectively.

For the same reasons modulated SELF non thermal fields can be potentially used for treatment of cells affected by many diseases like viral infections, AIDS, autoimmune diseases, etc., where the alteration of cell survival contributes to their pathogenesis.

According to another aspect of the invention, an apparatus for selectively interfering with pathological cells survival processes in vitro and in vivo has the characteristic of comprising means for generating static magnetic (S) fields crossing a working environment and means for generating electromagnetic extremely low frequency (ELF) fields in the working environment alone or in addition to the S fields.

Means are provided for modulating the S fields associated to the means for generating S fields and varying the intensity of the S fields between 1 and 100 mT and preferably from 1 to 30 mT.

Means are also provided for modulating the ELF fields alone or associated to the S fields at a frequency between 1 and 1000 Hz with intensity comprised between 1 and 30 mT. Preferably the ELF fields have a frequency between 10 and 100 Hz.

In a particular embodiment of the invention the means for modulating the S fields comprises program means that alternatively or in combination:

- set the intensity following a plurality of predetermined step values I_{s1}, I_{s2}, ▒, I_{sn} for corresponding time intervals T_1, T_2, ▒, T_n;
- set the intensity amplitude following a plurality of

predetermined step values I_{ELF1}, I_{ELF2}, ▒, I_{ELFn} for corresponding time intervals T_1, T_2, ▒, T_n;

- set the frequency following a plurality of predetermined step values f_1, f_2, ▒, f_n, for corresponding time intervals T_1, T_2, ▒, T_n;

- set an S/ELF ratio according to a plurality of predetermined step values I_{S1}/I_{ELF1}, I_{S2}/I_{ELF2}, ▒, I_{Sn}/I_{ELFn}, for corresponding time intervals T_1, T_2, ▒, T_n, .

Preferably, the program means set the S and ELF fields according to an overall intensity between 1 and 30 mT and respectively a ratio S/ELF comprised between 0,1 and 10 and, in a particularly preferred embodiment, according to an overall intensity between 1 and 10 mT and respectively a ratio S/ELF comprised between 0,5 and 5.

The time intervals are preferably set between 1 and 40 minutes.

At least a portion of the working environment is defined by walls permeable to the S and ELF fields. At least a portion of the working environment is also advantageously adjacent to a first and a second coil respectively and the means for modulating supplying to the coils DC and AC current respectively.

Brief description of the drawings

Several embodiments of the apparatus are shown in the attached drawings, given as an example and not limitative, wherein:

- Figure 1 shows a diagrammatical view of a first embodiment of an apparatus according to the invention;

- Figures 2 to 4 show block diagrams of a second third and fourth embodiment of an apparatus according to the invention, respectively;

- Figure 5A shows a diagrammatic function of field intensity versus time, as programmable in the apparatus according to the invention;

- Figure 5B shows a diagrammatic function of field

intensity of S and ELF fields versus time varying also the ratio with respect to each other field;

- Figure 5C shows a diagrammatic function of field intensity and frequency versus time.

Description of the preferred apparatus

In figure 1 the working environment is indicated as 1 and the wall as 2. The first and second coils are given the reference numbers 3 and 4 respectively. The modulating means are diagrammatically indicated by boxes 5 and 6 respectively, and are connected to AC and DC sources.

In figure 2 a different embodiment of the apparatus, used for interfering with pathological cells survival both in vitro and in vivo has two coils 23 and 24 located coaxial to each other at the opposite sides of the working environment 21. Variable transformers 25 and 26 are provided connected to a 50 Hz AC electric network 27. Switchable diode bridges 28 are provided to change the AC supply to the coils. A DC transformer 29a, a rectifier 29b as well as a timer 29c are provided supplying two plates 29 so that an up to 20kV/m static (or low frequency variable up to 1000 Hz) electric field, and preferably about 6 kV/m, may be created in the working environment 21 within preferred intervals, according to the experimental conditions.

In figure 3 a further embodiment is shown of the apparatus used for interfering with pathological cells survival in vitro having a SELF modulator 35 (1-100 Hz) and two coils 33 and 34 located coaxial to each other at the opposite sides of the working environment 31. An amplifier 36 is used between the modulator 35 and the coils 33 and 34, which are supplied with the same current creating in the environment 31 either an S or an ELF magnetic field.

Another embodiment of the apparatus according to the invention (fig. 4) used for interfering with pathological

cells survival both in vitro and in vivo has two Helmoltz coils 43 and 44 located coaxial to each other at the opposite sides of the working environment 41. An amplifier 46 is used between the modulator 45 and the coils 43 and 44, through a shunt element 47, which is also connected to a personal computer 49.

Each apparatus can be used for producing SELF modulated non thermal fields for interfering with pathological cells survival.

With reference to figures 5A to 5C, an example of the programming of the apparatus is given wherein the modulation of intensity, frequency and intensity ratio between S and ELF fields is carried out.

In figure 5A the way in which the intensity I may vary versus time. I_1, I_2, I_3, I_n are the intensity or field strength (mT) of either the S field, or of the ELF field, or the overall intensity $I_S + I_{ELF}$.

In figure 5B, when both fields S and ELF are present, it is possible to modulate not only their intensity or intensity amplitude, but also their ratio I_S/I_{ELF}. For example, different ratios 1; 1.5; 2; etc. can be used for time intervals T_1, T_2; T_3; etc.

Also the frequency can be modulated as shown in figure 5C. The frequency may also be modulated in two or more following intervals T_1, T_2, wherein the same intensity I_{1-2} is applied.

Starting from the basic examples of figures 5A-5C a sequence of modulated S, ELF, S+ELF fields can be produced that can also be repeated cyclically.

The method according to the invention will now be described in more detail by way of specific examples.

EXAMPLE 1

In this experiment the capability of inducing apoptosis by SELF magnetic field as a function of field intensity and frequency was studied in vitro.

Human colon adenocarcinoma cell line (WiDr) grown in confluent monolayers in T25 flasks was used for the experiment. For each exposure condition 6 flasks containing each about 10 millions cells were used, 3 exposed and 3 shame-exposed (i.e. not exposed).

During the exposure the flasks were held between two coils connected with a circuit providing DC and AC currents up to 100 Hertz. The temperature was continuously monitored and maintained at 37 ± 0,2 °C.

The exposure duration was 20 minutes for each experiment and the SELF field was maintained constant. After 3 hours the cells were treated with May- Grunwald-Giemsa. Apoptosis was assessed by counting the number of apoptotic nuclei per 10 high power fields (HPF) by using an optic microscope.

The amount of induced apoptosis was evaluated by the ratio between the number of apoptotic cells found in the exposure group and the number of apoptotic cells found in the shame-exposed group, that is the group not exposed to the magnetic fields according to the invention.

Table 1 reports the results obtained in different exposure conditions.

TABLE 1

exposure conditions	SELF field composition	frequency (Hz)	field intensity (Static + ELF rms) mT	apoptosis ratio
A	S (static)	-	(0.5 + 0)	1
B	S	-	(1 + 0)	1
C	S	-	(2 + 0)	1.2
D	S	-	(3 + 0)	2
E	S	-	(4 + 0)	2,3
F	S	-	(10 + 0)	2.2
G	S	-	(20 + 0)	2.2
H	S	-	(30 + 0)	2.3
I	ELF	16	(0 + 3)	2.2

L	ELF	33	(0 + 3)	2.2
M	ELF	50	(0 + 3)	2.1
N	ELF	50	(0 + 7)	2,1
O	ELF	66	(0 + 3)	2.2
P	ELF	83	(0 + 3)	2.3
Q	ELF	100	(0 + 3)	2.1
R	S + ELF	50	(4 + 3)	2.1
S	S + ELF	50	50% of time (3 + 1) 50% of time (4,5 + 1,5)	2.2

All the results were statistically highly significant (at the t Student test). From Table 1 we can see that the apoptosis effect appears at 2 mT and doubles starting from 3 mT.

Another important finding is that apoptosis doesn't depend upon SELF field frequency. In other words during the lifetime of the mechanism operating the biological effect (apoptosis) the ELF field is seen as essentially constant. This means that between the two hypothesised mechanism, free- radicals (occurring in a time scale of nano- to microsecond) and ion resonance-like mechanisms, the free radical one is playing the role [[39]Scaiano, 1994, [40]Engstrom, 1997].

EXAMPLE 2

In this experiment the selective effect of SELF magnetic fields was verified exposing three cell lines. Two lines were malignant, human colon adenocarcinoma cells (WiDr) and human breast cancer cells (MCF-7). The normal cell line was human lung fibroblast (MRC-5).

As in the example 1 each cell line was grown in confluent monolayers in T25 flasks. The experimental protocol was the same as in example 1. Six flasks (3 exposed and three shame-exposed) for each cell line were exposed for 20 minutes. Apoptosis was evaluated after 3 hours. The exposure conditions used were the R type of Table 1.

The results are reported in Table 2.

TABLE 2

cell line	apoptosis ratio
WiDr	2.1
MCF-7	1.4
MRC-5	1

As shown in Table 2 only cancer cells reported an apoptosis increment statistically highly significant, whereas the normal cell line didn't. The difference in percentage of apoptosis between the two cancer cell lines was expected due to the two different duplication times. In fact WiDr duplicates faster than MCF-7. The results were evaluated at t Student test.

EXAMPLE 3

In this example nude mice (nu/nu) bearing subcutaneous tumour masses were used to assess the influence of SELF magnetic fields on tumour growth inhibition.

Each mouse was inoculated subcutaneously with 10 million human colon adenocarcinoma cells (WiDr). Two experiments were successively carried out.

In the first experiment, 36 female mice were randomly assigned to 4 experimental groups, each formed by 6 exposed and 3 shame-exposed for a total of 24 animals exposed to 4 different SELF magnetic fields and 12 shame-exposed.

A Static Electric Field up to 6 kV/m was also applied to eventually take advantage of the different electrical behaviour between tumoral and normal tissues [[41]Thornton, 1984; [42]Barsamian, 1987]

In the second experiment 24 female mice were randomly assigned to 2 experimental groups, formed by 12 exposed to the SELF exposure condition which gave the best results among the four exposure conditions used in the previous

experiment (exposure condition number 4), and 12 shame-exposed.

All the mice of both experiments were divided into experimental groups after the tumor masses for each animal were palpable.

The animals were exposed for 70 minutes, once a day, for 5 days a week, for 4 weeks. During the exposure each mouse was put in a single box made of Plexiglas held between two coils connected to a circuit providing DC and AC current up to 100 Hz respectively.

Nude mice were kept under specific pathogen free conditions and supplied with ``ad libitum'' diet. All the tests were conducted in accordance with the protocol issued by N.I.H. (US National Institute of Health) and N.C.I. (US National Cancer Institute).

The tumor masses were measured twice a week and their volume calculated in mm^3 according to the formula:
[(major diameter) x (minor diameter squared)] / 2.

After 4 weeks the animals were sacrificed and autopsied. Tumor masses were extracted, weighed and measured. Portions of tumors were used for different analysis, i.e.

- immunoistochemical: Ki-67 antigen for proliferative index, p-53 antigen for the expression of p-53 gene;
- hystopathological: hematossilina-eosin staining for the assessment of number of mitosis;
- ultrastructural: electron microscopy;
- nucleic acid hybridisation: Tunel method for apoptosis evaluation.

In addition, the following organs were extracted from each animal for histologic examination to assess the treatment toxicity: brain, heart, kidneys, liver, lungs, axillary and inguinal limphonodes, mediastinal limphonodes, ovaries, skin, spleen, bone marrow, subcutaneous tissue (site of tumoral cell line implantation) as well as blood tests.

The obtained results are reported in Table 3 for the first experiment and in Table 4 for the second.

TABLE 3

exposure conditions	1	2	3	4	shame-exposed
exposure duration (min)	70	70	70	70	-
time averaged field intensity (Static + ELF rms) in mT	3	3	4	6	-
field variation in mT (min-max) Static; [min-max] ELF	(4-6) [2-2]	(1.5-4) [1-1]	(2-5) [1.5-3.5]	(2-5) [1.5-3.5]	-
constant field time duration (min-max) in minutes	(5-15)	(5-20)	(5-15)	(5-20)	-
time % with co-presence of Static and ELF fields	0%	50%	50%	100%	-
S/ELF ratio (min-max)	-	(0,5-5)	(0,5-5)	(0,5-5)	-
time % with Static field alone	50%	50%	50%	0%	-
number of mice	6	6	6	6	12
extracted tumor mass volume (mm^3)	1323 ± 304	1450 ± 288	920 ± 540	650 ± 205	1492 ± 559
extract tumor mass weight (g)	1.54 ± 0.22	1.6 ± 0.39	0.98 ± 0.56	0.96 ± 0.25	1.6 ± 0.5
number of apoptotic cells per 10 HPF	98 ± 23	115 ± 20	129 ± 25	129 ± 26	40 ± 17
p53 expression per 10 HPF	35.1 ± 0.11	43.8 ± 0.16	38.2 ± 0.06	28.7 ± 0.14	73.2 ± 0.14

TABLE 4

exposure conditions	4 (see tab. 3)	shame exposed
number of mice	12	12
extracted tumor mass volume	1139 ± 509 cm^3	1914 ± 793 cm^3
extracted tumor mass weight	1.4 ± 0.7 g	2.1 ± 0.6 g
apoptosis (assessed in 50% of mice only)	72.5 ± 9.3	37.0 ± 7.4
p53	35.6± 6.7	78.1±16.7
proliferative index	0.34 ± 0.08	0.45 ± 0.07
mitosis	24.1 ± 10.9	47.7 ± 10.1

The data reported in tables 3 and 4 show that SELF fields have an inhibitory tumor growth effect in vivo. This effect, found in both experiments, was statistically highly significant (in the first experiment, mostly for the exposure condition 4) at the Dunnet and t Student tests respectively.

At the histologic examination of 12 organs for each animal for all groups no differences were found between exposed and shame-exposed mice. No differences were also found in the blood tests. These findings prove the absence of toxicity related to the SELF fields treatment.

The ultrastructural analysis by electron microscope showed in the tumor cells of exposed animals many cellular alterations: presence of apoptotic bodies and condensed chromatin near the nuclear membrane characteristic of apoptotic events.

In addition a consistent result is represented by morphological modifications, increase of number and dimensions of mitochondria as well as number of nucleoli, presence of many vacuoles inside the cytoplasm. Non neoplastic cells (i.e. epithelial and stromal cells) showed no differences between exposed and shame-exposed animals in agreement with the absence of toxicity found in 12 normal organs examined in each animal.

The increment in apoptosis as well as the decrement in p53 gene expression found in exposed mice tumors (see tables 3 and 4) are statistically highly significant (t Student test)

Results reported in Table 3 and 4 are in agreement with those obtained in vitro and shown in Tables 1 and 2.

The effect induced by the SELF magnetic fields on p53 expression enforces the apoptosis results and is in agreement with the hypothesised biophysical mechanism (i.e. free radical recombination) by which the SELF fields have an anti-tumor effect through formation of reactive

oxygen species and the degradation of mithocondrial components.

EXAMPLE 4

In this experiment nude mice (nu/nu) previously subcutaneous inoculated with 10 million human colon adenocarcinoma cells (WiDr) were exposed to study the animal survival.

After the cell inoculation 2 groups of mice were randomly formed respectively of 16 animals exposed and 17 shame-exposed. The mice of the former group were exposed 70 minutes once a day, for 5 days a week, for their entire life beginning after 24 hours after the tumor inoculation.

The exposure conditions were the same of the experiment the results which are reported in Table 4.

As in the previous example, the mice were maintained under specific pathogen free condition supplied with ``ad libitum'' diet. All the tests were conducted in accordance with protocol issued by N.I.H. and N.C.I.

The antitumor effectiveness of the treatment was evaluated by using the N.C.I. formula: ratio between exposed and shame-exposed animals of the average animal life span. This average was evaluated summing for each experimental group the time of survival divided by the number of animals. The effectiveness is obtained when the N.C.I. formula gives as result an index equal or greater than 1.25.

Table 5 reports for each experimental group, the number of living animals at different times (days) from the beginning of experiment.

TABLE 5

living mice exposed/ shame-exp. (days)	16/16 (48)	16/15 (73)	15/14 (76)	14/14 (84)	13/14 (87)	12/14 (88)
living mice exposed/ shame-exp. (days)	12/13 (97)	12/12 (107)	10/12 (109)	10/10 (114)	10/9 (115)	9/8 (125)
living mice exposed/	9/7	8/6	8/5	8/4	7/4	7/3

shame-exp. (days)	(149)	(153)	(155)	(157)	(163)	(173)
living mice exposed/	6/3	6/2	6/0	5/0	4/0	3/0
shame-exp. (days)	(183)	(192)	(194)	(195)	(203)	(257)
living mice exposed/	2/0	1/0	0*/0			
shame-exp. (days)	(276)	(323)	*sacrificed (326)			

The N.C.I. formula applied to the results reported in Table 5 gives an index equal to 1.31, that is greater than 1.25 . After 194 days 6 exposed mice were alive whereas all shame exposed mice were dead.

The foregoing description of specific embodiments will so fully reveal the invention according to the conceptual point of view, so that others, by applying current knowledge, will be able to modify and/or adapt for various applications such embodiments without further research and without departing from the invention, and it is therefore to be understood that such adaptations and modifications will have to be considered as equivalent to the specific embodiments. The means and the materials to realise the different functions described herein could have a different nature without, for this reason, departing from the field of the invention. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

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